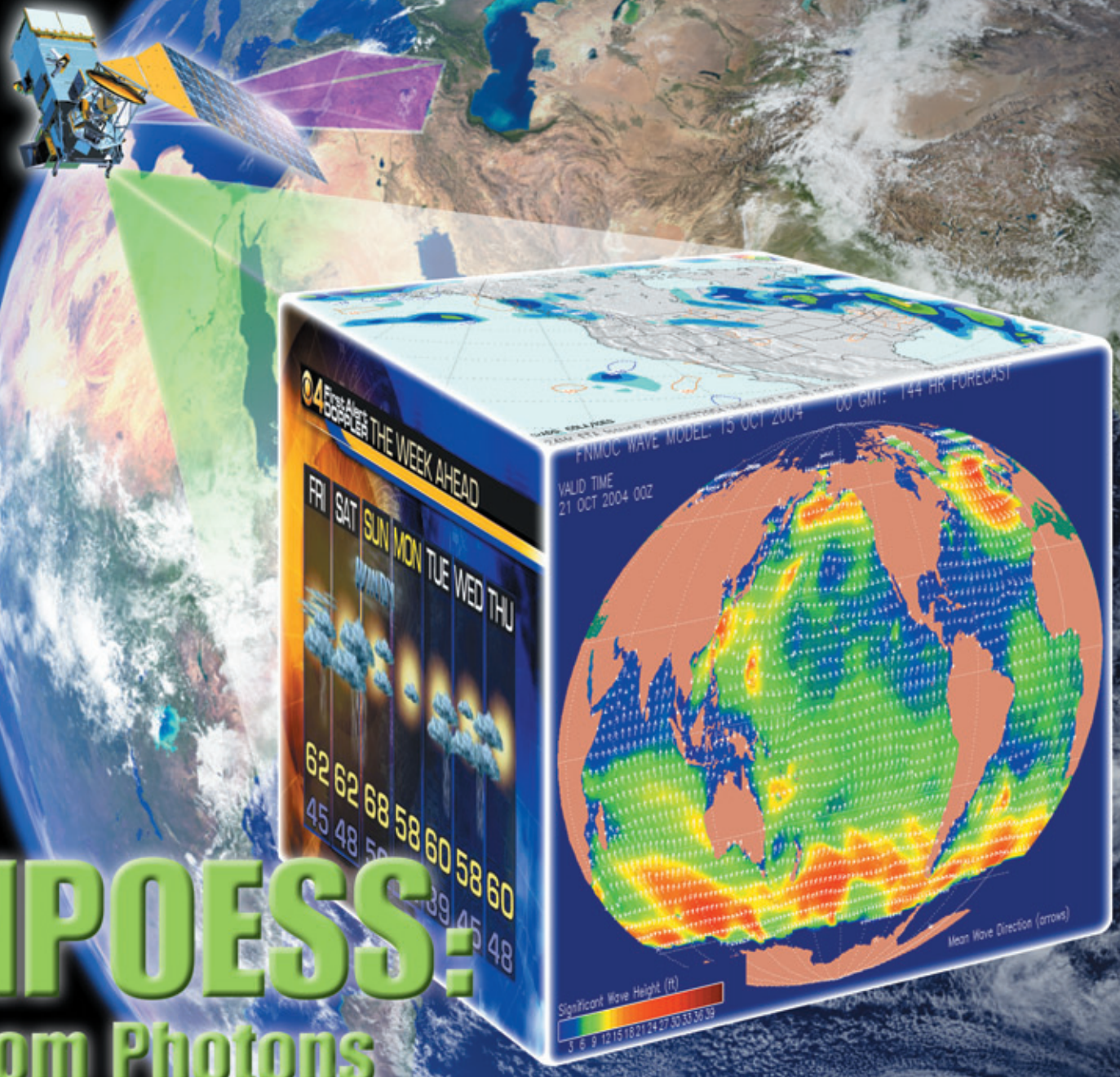
Volume 13, Issue 7
November 2004

EOM

Earth Observation Magazine

Geospatial Technologies in Your World



NPOESS: From Photons to Forecasts

A GTC America Publication

NPOESS: From

Providing Critical Data for Weather Predictions

Dave Jones
Mike Haas
Craig Nelson

This is the sixth in a series of articles on the National Polar-orbiting Operational Environmental Satellite System (NPOESS). As the backbone of the Global Earth Observation System of Systems, NPOESS will become the main data source for Numerical Weather Prediction (NWP). NPOESS will help to improve forecasts of the weather and Earth's environment through higher quality and more timely land, sea, atmosphere, and space observations.

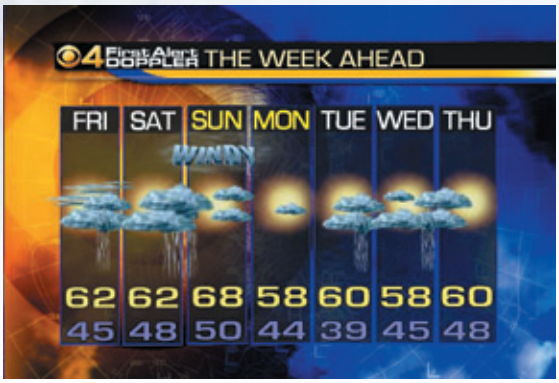


Figure 1 *A 7-day Outlook graphic is shown in just about every weather update and is a very important graphic in television weather segments across the nation. People always want to see what the weather might be like for the upcoming weekend…even on Monday. Terry Eliasen, CBS4 meteorologist and weather producer says, "Numerical weather prediction (NWP) is the basis for each and every forecast we make at CBS4. With each year that passes it becomes more and more reliable, and it still amazes me that anyone can log on from their home computer and see all the numerical weather models from their home!"*

Introduction: Numerical Weather Prediction

"Coming up next, your seven-day weather outlook." "I'll be back with a look well into next week…." Ever wonder how the weather forecaster on television can look into the future each and every day? Have you thought about where forecasters get the data they use to make predictions across the globe?

Since the 1950s, meteorologists have used improving computer models in a scheme called Numerical Weather Prediction (NWP) to produce the guidance for the forecasts that are produced for a wide range of purposes and by a wide assortment of people, from an anxious

Figure 2 *This picture was taken circa 1965 and shows a meteorologist at the console of the IBM 7090 electronic computer at the National Meteorological Center, now known as the National Centers for Environmental Prediction (NCEP). This computer was used to process weather data for short and long-range forecasts, analyses, and research. In 1965, a short-term forecast was defined as a 2-day forecast and a long-range forecast was defined as a 4-day forecast. Today a short-term forecast is defined as 3-4 days and a long-range forecast is out to two weeks. Image Courtesy: NOAA Image Library*

Photons to Forecasts

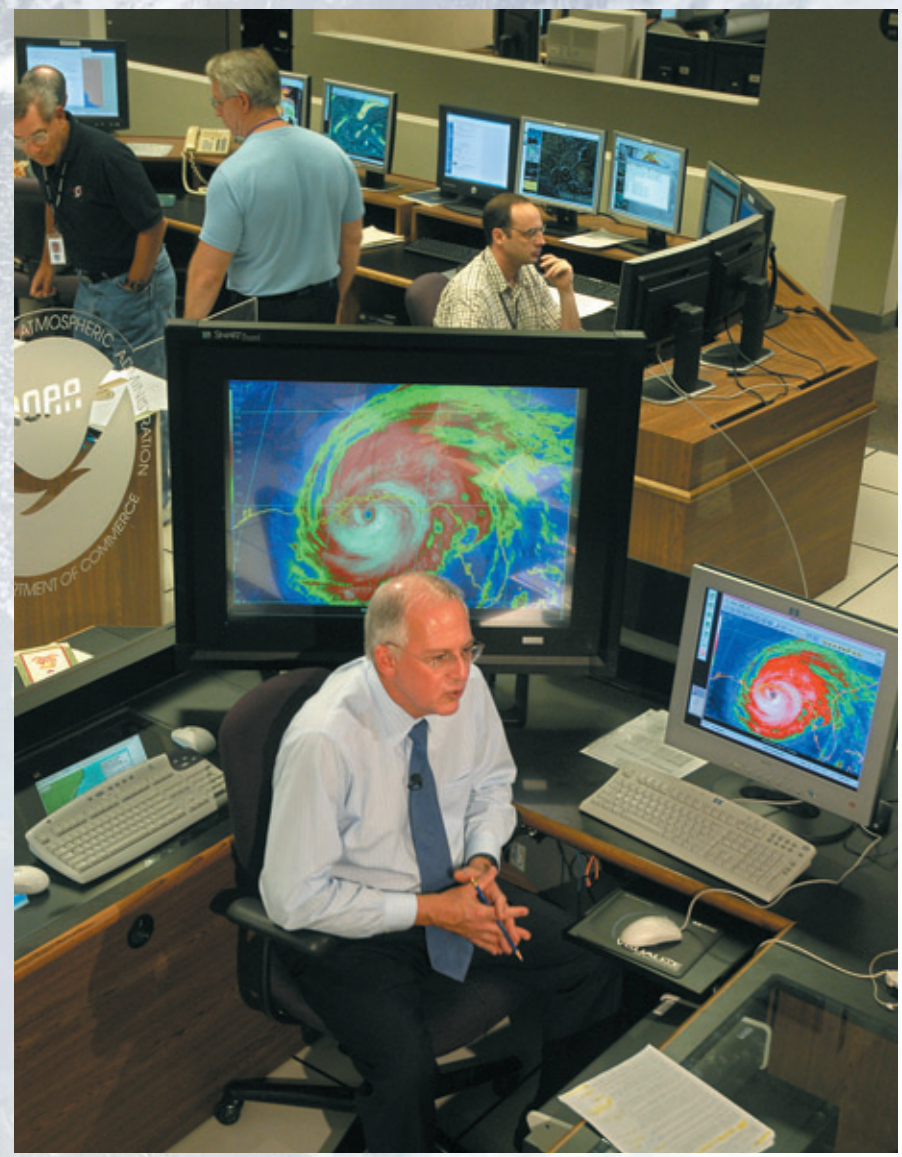


Figure 3 *National Hurricane Center (NHC) Director, Max Mayfield answers a television anchor's questions about Hurricane Ivan, early Thursday, Sept. 16, 2004, at the hurricane center in Miami. Advances in computer technologies, forecasts, and expertise have allowed the NHC to communicate directly with the media in real-time to keep citizens, decision makers and the media informed of the latest movements of hurricanes. Advances in environmental observation satellites such as NPOESS and GOES-R will deliver higher resolution images and data faster for immediate use in NWP models to keep the public aware of any potential change in movement or intensity of these deadly hurricanes. Image courtesy: AP World Wide Photos*

bride and groom planning their outdoor wedding to a commander planning a military operation. Advances in computer technology, our improved understanding of the underlying physics used in modeling, and better observations are making weather forecasts timelier and more accurate. Environmental satellites play a key role in providing critical input data worldwide for numerical weather prediction models.

The sophisticated computer models used in weather prediction are driven by huge volumes of data with more than 125 million observations coming in daily, mostly from satellites. According to Dr. Louis Uccellini, the Director of the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Prediction (NCEP), more than 99 percent of the data used for making weather forecasts is derived from satellites, primarily from polar-orbiting environmental satellites (*e.g.*, NOAA's Polar-orbiting Operational Environmental Satellites—POES). Satellite observations are combined with in situ observations and fed as input into the models in a process known as data assimilation. Satellites are especially important in providing observations in parts of the world where in situ data are few and far between, such as the oceans and uninhabited regions. "All forecasts are local and all [forecasts] start with the Global Observation System," said Dr. Uccellini. "The global observations pass through numerical weather prediction models and are projected out to 1 to 2 to 3 and on out to 14 days."

Improved Satellites for Better Forecasts

With the societal importance of accurate and timely weather forecasts in mind, the National Polar-orbiting Operational Environmental Satellite System (NPOESS) is being designed to improve predictions even further. NPOESS sounders and imagers will bring increased fidelity (improved resolution, accuracy, and precision) to the data, reducing the initial errors introduced into the models from observations. Equally important is an improvement in data latency, the time from when a photon is sensed by the satellite to the time a product is produced by the system. Current systems

take around two and one-half hours to assimilate data into a model and produce an output. A large part of the delay comes from ingesting satellite data. NPOESS will use an innovative system to reduce the time it takes to obtain data by nearly one hour. A decreased latency should provide a tremendous benefit to modelers as well as to the users of model output. "We get as many kudos from having a 99.5% on time delivery as we do for increasing accuracy," said Dr. Uccellini, "we listen to our customers when they say lost time in distributing model forecasts is a waste of resources."

To prepare for the increased data volume that will be available from NPOESS, agencies from within the United States government have banded together to fund the Joint Center for Satellite Data Assimilation. The center focuses on data assimilation, bridging the gap from making satellite observations to ingesting these data into numerical models. "Five years ago," said Dr. Uccellini, "it would take three to four years to test and use new satellite data; on a five-year satellite you lose 20-40% of the effective life." The Joint Center's goal is to have data ready for use within one year after launch and available for use in the environmental community as soon as possible.

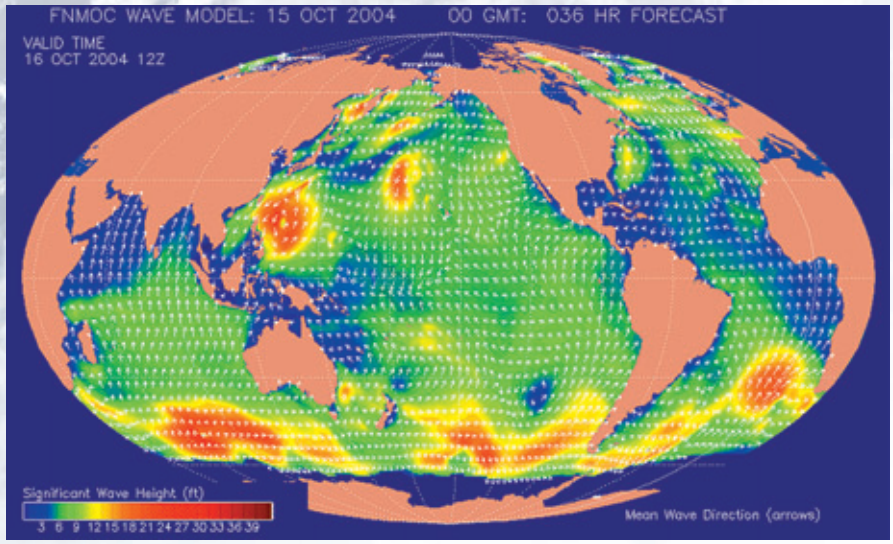


Figure 4 *WAVEWATCH III (Tolman 1997, 1999a) is a third generation wave model developed at NOAA/NCEP and used at FNMOC to predict global wave heights. These predictions significantly aid military operations and commercial operations at sea and along the coastlines of landmasses across the world. Forecasts are made several times per day, which require input from satellites and ground-based* in situ *measurements such as buoys to keep the models on track. Image courtesy: Fleet Numerical Meteorology and Oceanography Center (FNMOC):* https://www.fnmoc.navy.mil/PUBLIC/WAM/wam.html

Military Weather Forecasting

In addition to the country's civilian meteorologists and public, the users of numerical weather predictions include those who plan and execute military operations. Both the Air Force Weather Agency (AFWA) at Offutt Air Force Base and the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) at Monterey have worldwide and regional NWP models to support military missions. Much of their input data comes from satellites as well. According to Dr. Nancy Baker of the Marine Meteorology Division of the Naval Research Laboratory (NRL) in Monterey, the U.S. Navy's global and mesoscale numerical weather prediction systems currently assimilate a wealth of observations from both geostationary and polar-orbiting satellites. These observations, particularly in data-sparse regions, are critically important for initializing the NWP models and stratospheric analyses used to provide tactical weather support to the U.S. Navy, Marine Corps, Air Force, and other Department of Defense (DoD) activities, as well as some civilian activities.

FNMOC assimilates data from a variety of satellites ranging from the National Aeronautics and Space Administration's (NASA) research missions to operational NOAA and DoD satellites. Data, such as precipitable water, wind speed and direction, and energy levels (known as radiances) are received from sensors similar to those that will be on NPOESS. This fall, NRL/Monterey will test the assimilation of vector ocean surface wind retrievals from WindSat, a risk reduction mission for the Conical-scanning Microwave Imager Sounder (CMIS) instrument that will be on NPOESS.

Future plans at NRL include developing data assimilation methods for the Atmospheric Infrared Sounder (AIRS) on NASA's Aqua spacecraft (in preparation for the NPOESS Cross-track Infrared Sounder (CrIS) sensor), and adding Global Positioning System (GPS) radio occultation assimilation. Excellent progress has already been made on the development of a four-dimensional NAvy Variational Data Assimilation System using the accelerated representer method (NAVDAS-AR), a system that will be enhanced with more timely NPOESS data. Also on the books is a plan to develop the aerosol assimilation components for the Navy Aerosol Analysis and Prediction System (NAAPS), again relying heavily on satellite observations. Overall, NRL is actively developing a suite of data assimilation techniques to handle the wealth and variety of satellite observations that will be available through NPOESS.

AFWA leads the world in meeting the operational challenges of analyzing and forecasting global cloud cover. Global and regional products generated from AFWA's Cloud Depiction and Forecast System II (CDFS II) are used to directly support the warfighter. CDFSII processes data from a variety of polar-orbiting and geostationary satellites to produce quantitative, worldwide cloud analyses, and forecasts. The higher spatial and temporal resolution cloud imagery data that will be available from the Visible/Infrared Imager Radiometer Suite (VIIRS) instrument on the NPOESS Preparatory Project (NPP) and NPOESS will lead to significant improvements in AFWA's ability to forecast clouds accurately and far enough in advance of mission times to really help the warfighter.

It is anticipated that improved information from NPOESS will help to provide

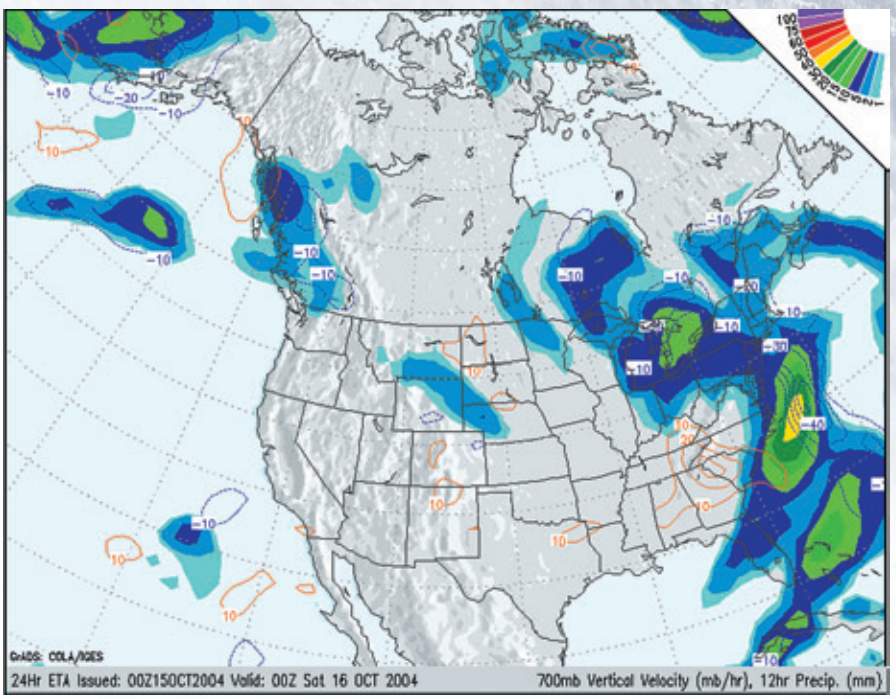


Figure 5 *This image is an example of a numerical weather model output of forecast precipitation and vertical velocity (a component that is important for the formation of rain/snow and thunderstorms). This particular example is from the ETA model, just one time period in a string of forecast parameters that are produced four times per day when the ETA model is run. Ninety-nine percent (99%) of the input data used in most numerical weather forecast models comes from satellites.*

the best possible input to numerical weather prediction models and improve weather forecasts for worldwide users, both military and civil. Specific payoffs are likely to include better analysis and prediction of marine winds, slant-path visibility, and clouds, all of which are important for landing and launching aircraft from carriers and other tactical applications; improved specification of low-level temperature and humidity structures; improved hurricane track and intensity forecasts (vital for safety of people and assets); and improved upper atmosphere analyses and predictions. While the costs of developing the data assimilation tools for NPOESS observations are significant, recent successes at NRL and other NWP centers have clearly demonstrated that substantial gains in analysis and forecast skill can be made when improved satellite observations are properly assimilated.

From Weather to Climate

Sea surface temperature (SST) is an important input or boundary parameter for numerical weather prediction and climate models. Heat transfer from the ocean to the atmosphere in part drives weather systems, fueling hurricanes and tropical cyclones. The use of more accurate SST information in models is yielding demonstrable improvements in medium- to long-range forecasts. Space-based sensors like VIIRS on NPOESS can only measure the temperature of the surface "skin" (top few millimeters) of the ocean. However, when SST data are combined with measurements of sea surface height and *in situ* profiles of subsurface temperatures, through numerical ocean models, the full three-dimensional structure of the ocean's temperature field can be resolved. In the NPOESS era, SST data from VIIRS, sea surface height measurements from the NPOESS Radar Altimeter, and subsurface temperature measurements from observing systems such as the autonomous ocean profiling Argo floats will provide the primary input data for NWP models. Over longer time scales, NPOESS ocean temperature data will be used to monitor the onset and decay of El Niño/La Niña conditions in the Pacific Ocean and to yield clues about shifts in the "oceanic conveyor belt" that may drive large-scale changes in climate.

The study of the environment and prediction of weather are critical for everyday life, but they also provide important information for other uses, such as military operations and in the study of longer-term climate change. Data from NPOESS will play a key role in all of these applications. In the next issue, we will take a more detailed look into satellite data and the study of the Earth's changing climate.

About the Authors

Dave Jones is Founder, President and CEO of StormCenter Communications, Inc. *(stormcenter.com)*. He is also President of the Foundation for Earth Science and sits on the Executive Committee of the ESIP Federation *(esipfed.org)*. Dave can be reached at *dave@stormcenter.com*.

Mike Haas is the Principal Director for the Aerospace Corporation at the NPOESS Integrated Program Office (IPO). Prior to working for Aerospace, Mike was a meteorologist for the U.S. Air Force for 27 years. He can be reached at *Mike.Haas@noaa.gov*.

Craig Nelson is the former Executive Director of the NPOESS Integrated Program Office (IPO). He is employed by General Dynamics Advanced Information Systems as a support contractor to the IPO and can be reached at *Craig.Nelson@noaa.gov*.

It's been gathering momentum for years. Now its strength is extraordinary. Northrop Grumman is an environmental sensing powerhouse. Building upon a legacy of innovation, Northrop Grumman is prepared for virtually any remote sensing mission. And we are applying our systems, spacecraft, sensor, data distribution and integration expertise to transform complex ideas into tomorrow's reliable systems. From the National Polar-orbiting Operational Environmental Satellite System to the Advanced Weather Interactive Processing System, from the Space Weather Analysis and Forecast System to NASA's Earth Observing System, our potential is matched only by the bounty of the Earth itself.

www.northropgrumman.com

NORTHROP GRUMMAN DEFINING THE FUTURE™